

TELEMEDICINE FOR THE CANADIAN FORCES

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Military Space Applications

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

TELEMEDICINE FOR THE CANADIAN FORCES: WHAT IS A VIABLE
SATELLITE MEANS FOR THE CANADIAN FORCES TO DELIVER
TELEMEDICINE INFORMATION BETWEEN A DEPLOYED FORCE AND A
CANADA BASED SUPPORTING HOSPITAL? By MAJ Timothy W. Walrod, USA,
72 pages

Several nations currently use commercial off-the-shelf technology to provide telemedicine for military and civilian purposes. The vast distances and undeveloped regions that the Canadian Forces (CF) work across requires a transportable, satellite accessible telemedicine system that meets their requirements. The purpose of this thesis was to conduct an exploratory descriptive analysis to compare existing deployable telemedicine systems and identify which of those would best meet the telemedicine requirements of the CF as a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada based supporting hospital. A comparative analysis was completed in order to recommend a telemedicine system that the CF can implement and deploy with.

Of the three systems analyzed, all are viable in a comparison of systems using a non-weighted set of criteria. The capabilities and limitations of a system such as cost, weight, and bandwidth can be compared individually and as an overall system. All three telemedicine systems studied are viable satellite means that the CF can use to deliver telemedicine information. The CF can now tailor a satellite delivered telemedicine system that meets the most important criteria of their requirements.

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To my father Mr. F.F. Walrod, and my mentors and friends Mr. Michael A. Proctor and Mr. Alistair Cole who started me on this path.

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ACRONYMS

CF	CANADIAN FORCES
CFHIS	CANADIAN FORCES HEALTH INFORMATION SERVICES
COTS	COMMERCIAL-OFF-THE-SHELF
DCIEM MEDICINE	DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL
DMS	DEFENCE MEDICAL SERVICES
DOD	DEPARTMENT OF DEFENSE
EKG	Electrocardiogram (Abbreviated ECG in Canada)
INMARSAT	INTERNATIONAL MARITIME SATELLITE, LIMITED
NDHQ	National Defence Headquarters
PANAMSAT	PAN AMERICAN SATELLITE, INCORPORATED
SMART	SPECIAL MEDICAL AUGMENTATION RESPONSE TEAM
TATRC CENTER	TELEMEDICINE AND ADVANCED TECHNOLOGY RESEARCH
UK	UNITED KINGDOM
VSAT	VERY SMALL APERTURE TERMINAL

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Table 1. Telemedicine Systems Evaluated Against Criteria

Criteria	Systems					
	MC3T-VSAT		MC3T		DMS	
	Reqmt	Score	Reqmt	Score	Reqmt	Score
Consulting (Voice)						
EKG/ECG Readability						
Digital Radiographic Imagery						
Transmission Path (in Kbps)						
Space Segment Potential Increase (in Kbps)						
Training Required (in Man-hours)						
Weight and Cubic Size (Kg and m3)						
Comms and <u>Weight in Kg</u>						
Medical Equipment <u>Cubic Size in m3</u>						
Cost (in U.S. Dollars)						
<u>Space Segment per month</u>						
<u>Comms and Medical Equip</u>						
Overall Score						

Table 3. Telemedicine Systems Evaluated Against Criteria

Criteria	Systems					
	MC3T-VSAT		MC3T		DMS	
	Reqmt	Score	Reqmt	Score	Reqmt	Score
Consulting (Voice)	2 x Toll	1	Vox Rec	0	Vox Rec	0
EKG/ECG Readability	Fax	0	Fax	0	Fax	0
Digital Radiographic Imagery	2.11 Mpixels	0	2.11 Mpixels	0	1.41 Mpixels	-1
Transmission Path (in Kbps)	64 kbps- 1.544 Mbps	1	64 kbps	0	64 kbps	0
Space Segment Potential Increase (in Kbps)	2 Mbps	1	128 Kbps	0	128 bps	0
Training Required (in Man-hours)	16 Mhours	-1	8 Mhours	0	6 MHours	1
Weight and Cubic Size (Kg and m3)		-1		0		1
Comms and Medical Equipment	Weight in Kg	1109 kg	53 kg		38 kg	
	Cubic Size in m3	8.42 m3	.17 m3		.15 m3	
Cost (in U.S. Dollars)	57.8 K	-1	55 K	0	24.5 K	1
Space Segment per month	4796		1950		1950	
Comms and Medical Equip	54 K		53 K		22.6 K	
Overall Score		0		0		2

CHAPTER 1

AN INTRODUCTION OF TELEMEDICINE AND THE CANADIAN FORCES

As of July 2000, the Canadian Forces (CF) medical community had not fully defined their telemedicine requirement to deliver telemedicine information to and from a deployed force and a Canada based supporting hospital. Several nations currently use commercial off-the-shelf technology to provide telemedicine for military and civilian purposes. The vast distances and undeveloped regions that the CF work across requires a transportable, satellite accessible telemedicine system that meets their requirements. The purpose of this paper was to conduct an exploratory descriptive analysis of existing systems to identify three or more that will best suit the CF needs and then do a comparative analysis in order to recommend a telemedicine system that the CF can implement and deploy with.

Research Questions

Primary Question: What is a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada based supporting hospital?

Subordinate Question Set 1: What is the requirement in deliverable medical service? What is the bandwidth that the CF requires? Will there be a baseline of medical service required for every mission? Does the CF medical community need the telemedicine service capability to be expandable to include additional services?

Subordinate Question Set 2: Are there other systems currently in use that the Canadian Forces can use? Is the US Department of Defense (DOD) deployable telemedicine model valid for application to the CF? Is there a way to piggyback or dovetail with the US DOD in either terminal equipment or satellite bandwidth?

Background of the Problem and Research Question

Telemedicine is directly from the Greek words for medicine at a distance.¹ This can be as simple as a telephone call from one medical professional to another or as complex as a live real time video interview of a patient by a doctor 5,000 miles away. The US Army Telemedicine and Advanced Technology Research Center's definition of military telemedicine follows:

Military telemedicine reflects the application of physiological and medical knowledge, through simulations and sensing and effector systems integrated with information and telecommunication technologies, to facilitate operational and medical decision making, enhance medical training, and deliver medical treatment across all barriers. From the medical perspective, advances in information and telecommunication technologies can be exploited to military advantage through their combined application with advanced biomedical technologies. Telemedicine derives capability from technological advances across a number of fields including telecommunications, space sciences, materials science, computer and software engineering, artificial intelligence, perceptual psychology, robotics and medicine. Telemedicine reflects health care's contribution to and utilization of the theater-wide military command and communications system.²

Currently, telemedicine is found in this spectrum of uses in many countries around the world. Civilian and military medical personnel use this to provide service to remote communities or to support developing regions and to seek medical advice from medical specialists when face-to-face consultations or referrals are not feasible. The CF medical

specialist issue is compounded by not having a military hospital that operates twenty-four hours a day, seven days a week with all of the required specialists that a deployed force may need. The CF do not have a medical infrastructure the size of the US DOD on which to fall back once the telemedicine information has been delivered. The Canada-based required medical services and expertise may have to involve a civilian hospital(s) in Canada to support deployed CF.

The primary question emerged when CF communications requirements were reviewed from 1998 to 1999. These requirements along with other command and control, logistic, and intelligence requirements were examined with the intent to deliver service via satellite in a combination of civilian and military satellite bandwidth. Many of the places the CF deploy have no land-based (terrestrial) commercial or military communications infrastructure to carry the required bandwidth to and from Canada. This terrestrial infrastructure would include host nation microwave, fiber optic, undersea cable, and the like. Satellite communication was determined as the most viable and dependable means for meeting the requirement, particularly from underdeveloped remote regions of the world. Information systems to include telemedicine would be transmitted over terrestrial communication means as they become available.

There will be a benefit to the CF and the Canadian civilian hospitals by having telemedicine treatment for deployed CF soldiers. The benefits are several: CF members are treated with the highest quality medical available in a manner as quick as possible in remote locations, monies come into the civilian hospital for services rendered, the “human factor” of helping their deployed military, the professional development of treating cases that would not normally be found in Canada (landmine strike wounds,

complex weapons wounds, tropical diseases, etc.), and medical assistance to domestic Canadian civil authorities during natural disasters. The US and its military forces will benefit from a CF telemedicine system in cases where both country's forces are in the same operational area and mutual support can be arranged. Recent areas of colocated operations include Honduras during the Hurricane Mitch relief effort and the Balkans.

The Canadian civilian hospital(s) with associated expertise may be required and have additional costs associated with that access to the expertise. Expertise in both English and French will be required in multiple medical specialties such as trauma, orthopedics, radiology, and psychology. Completing the CF telemedicine requirement as scheduled this year is vital in determining the satellite bandwidth needed to deliver the medical service. The "must have," "would like to have," and other requirements are being worked in Canada at this time.

Assumptions

In order to conduct the investigation of which systems would be meet the requirement, the investigator made the following assumptions, which the CF have validated.

A commercial off-the-shelf (COTS) or military telemedicine system and required satellite communications equipment would be available. Currently the US DOD and the United Kingdom (UK) Ministry of Defence use telemedicine equipment with commercial satellite bandwidth and communications systems. Many civilian hospitals,

medical communities, and institutes of higher learning also use telemedicine via satellite both in Canada and the US.

The CF would refine the desired deliverable medical services as much as possible in the next five months. It was valid to assume that the investigator would be participating in this process with the approval of the CF and would be able to refine the requirements based on CF guidance.

The CF medical community would determine a requirement that would be approved by the National Defence Headquarters (NDHQ). NDHQ is the equivalent of the US Joint Chiefs of Staff and Pentagon. The CF point of contact would be informing and working with the members of the CF NDHQ during the next year keeping them informed of the study progress as required.

There would be sufficient ability for Canadian civilian hospital(s) to provide the twenty-four hour, seven day a week expertise or CF medical staff will be made available as required. This has been discussed in concept with the CF telemedicine point of contact. CF doctors currently work at different civilian hospitals across Canada to maintain skill proficiency and as part of study programs.

All cost figures for satellite bandwidth and the terminal equipment to transfer the medical data would be available, including all technical specifications that the appropriate CF departments can pursue upon the validation of this study. The cost figures can be accurately estimated and in some cases confirmed by pricing obtained from commercial vendors and or militaries or civilian agencies that currently use telemedicine systems. All costs are reflected in US Dollars. Prior to implementation of any telemedicine system, all prices and services would be negotiated under competitive

contract or via a “buy and try” program by the appropriate Canadian Department of National Defence agency.

The Canadian civilian hospital(s) would support CF deployed operations. Currently, Canadian civilian hospitals support the CF for many medical services and are reimbursed by the Government of Canada. This additional service may cost either additional money or military personnel to assist.

Definitions

Bandwidth. Bandwidth can be defined as “the maximum frequency (spectrum) measured in Hertz or cycles per second, between the two limited frequencies of a transmission channel; the range of frequencies of a transmission channel; the range of frequencies that can be carried by a transmission medium without undue distortion; a measure of information carrying capacity of a communications channel.”³ Bandwidth is the size of the pipe, whether copper cable, fiber optic cable, or satellite. The power required in sending and receiving that bandwidth factors into the means as well as the cost. The more bandwidth required from the satellite, the more expensive the service is. To get the same amount of bandwidth, generally a small antenna dish requires more power (and costs more) than a big antenna dish that needs less power (and costs less). The size of the antenna and the weight of the equipment affect how deployable the satellite terminal and peripheral equipment is. After determining the requirements (what telemedicine services, what encryption (if any), and method of deployment), one can pursue the type of satellite equipment and bandwidth. For the purpose of this study, specific medical requirements and the bandwidth each requirement needs were delineated and compiled for a total sum bandwidth required.

Canadian Forces (CF). This is the Canadian term for their military. This includes the Canadian joint and strategic forces, the Army, Navy, and Air Force. This term is abbreviated CF in the paper.

CF Medical Community. This collective term is used for the CF medical personnel regardless of branch of service unless specified. This term also includes the national-level medical plans, operations, and requirements personnel as well as CF personnel deployed or in Canada.

Requirement. This is a specific set of operational needs. For this study, it was not possible to draw from a Canadian statement of capability deficiency or statement of requirement that has been approved by a national-level headquarters. The senior member of the CF telemedicine working group established the set of requirements used in this study. A requirement can be as simple as a radio net, a certain amount of services to be delivered, the parameters of those services, and the like. The term requirement is used for a specific type of service or capability based on an approved (or approved working draft) operational need.

Telemedicine. The definition cited on page 2 of this chapter defines telemedicine in its broadest military sense. The CF is currently defining telemedicine under a telehealth concept to be defined further in the future. The medical services required by the medical community from one location to another via a communications means is the intent, and simply put, this can range from a faxing capability to real-time video. For the purpose of this paper, the term telemedicine refers to the medical services

required by the CF via satellite telecommunications means as determined by the scope of their requirement.

Viable. Viable was determined in concert with the CF medical requirements. Factors that influence viability include all “must” telemedicine requirements, as many “preferred” requirements as possible, estimated cost of satellite bandwidth, estimated cost of terminal equipment, and ease of interface to Canadian civilian hospital infrastructures. Individual requirements are defined and a criteria matrix is shown in Chapter 3 of this thesis. The source documentation and definition for all US military satellite system criteria was used as a framework.

Limitations

The limited time available to conduct research and refine requirements reduced the investigator’s ability to capture all possibilities and permutations of systems that could meet the requirements. Lack of funds to collect data and to test proposed systems or to conduct “buy and try” prototype experiments of proposed systems limited the depth and extent of the investigation. The investigator has limited research experience. It was not feasible due to time and funding constraints to use experimental design to control an experimental group and complete a statistical analysis and comparison between different systems. In lieu of comparing a control system with experimental systems the investigator used a decision matrix with defined requirement criteria.

Study Scope and Delimitations

Scope of Study. This study focused on potential systems for delivering

telemedicine service between deployed CF personnel and a Canada-based hospital in order to make recommendations regarding a telemedicine system that the CF can implement and deploy with. This study did not include hospital ships or hospitals based in other nations. This study focused on satellite-delivered telemedicine services. The leasing, buying, or using land-based communications systems was not addressed in this study except as required in the estimated costs to deliver telemedicine to or from a satellite ground terminal to a hospital or medical facility. The Canadian Department of National Defence level entities would be required to approve the requirement and the funding of an approved solution. The exact funding and methodology for implementation is outside of the scope of this study.

Delimitations. The investigator determined in advance that a limited number, (not more than three) types of services and terminal equipment to deliver telemedicine would be compared in this study. Systems that were not deployable, that were under initial development, or that did not have information available in English were not used. The services and types of equipment were based on existing models and services currently in use at the time of the study.

Significance of the Study

The intent of this study was to show a viable means of delivering telemedicine service to the CF. At the time of the study the CF had to evacuate a CF member back to Canada, use another nation's equipment, or send a doctor to the location of that CF member. The impact of telemedicine would be increased medical service to the deployed

CF member by a faster response time and increased effectiveness of Canadian medical expertise both military and civilian, based in Canada.

There will be a benefit to the CF and the Canadian civilian hospitals by having telemedicine treatment for deployed CF soldiers. The benefits are several: CF members are treated with the highest quality medical service available in a manner as quick as possible in remote locations, monies come into the civilian hospital for services rendered, the human factor of helping their deployed military, the professional development of treating cases that would not normally be found in Canada (landmine strike wounds, complex weapons wounds, and tropical diseases), and medical assistance to domestic Canadian civil authorities during natural disasters. The US and its military forces will benefit from a CF telemedicine system in cases where both country's forces are in the same operational area and mutual support can be arranged. With the development of a CF telemedicine system, the US DOD and CF DND can coordinate critical medical service capabilities on deployments in the future. The additional expertise in satellite system setup, bandwidth management, and application of technologies is of great benefit when multi-national force headquarters and support areas have limited assets and personnel. The US and Canada are members of the NATO Military Medical Group Subcommittee on Telemedicine. The US has been appointed the custodian for the development of a telemedicine Standard NATO Agreement (STANAG) and chairs the Telemedicine Subcommittee. This Subcommittee is responsible to coordinate for the planning, integration, and standardization of telemedicine systems. With Canada joining the US, UK and others with a fielded telemedicine system based on

NATO standards, the opportunity is present for an even greater use of common telemedicine assets, shared expertise and timely help to the forces.

The purpose of this paper was to conduct an exploratory descriptive analysis of existing systems to identify three or more that will best suit the CF needs and then do a comparative analysis in order to recommend a telemedicine system that the CF can implement and deploy with. The study outcome may be part of an interim state or first step in the overall solution process. This interim state could be offering a baseline of deliverable telemedicine services. Improvements in technology and a decrease in the costs of services and equipment could provide the end state of a fully viable CF telemedicine system.

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¹LCol David J. Vassallo, Defence Medical Services Telemedicine Unit, Royal Hospital Haslar, Gosport, Hants, PO 14 2DL, *United Kingdom Journal of Telemedicine and Telecare*, Volume 5 Supplement 1 (1999): 117.

²Telemedicine & Advanced Technology Research Center Home Page; [On-line] Available from <http://www.tatrc.org/telemedicine.html>; Internet: accessed 2 December 2000.

³Jim Reid, *A Telemedicine Primer: Understanding the Issues*, (Billings, Montana: Artcraft Printers, 1996), 104.

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CHAPTER 2

TELEMEDICINE SYSTEMS

There is a large amount of information available on military telemedicine, particularly in the US. Telemedicine sources available include the DOD, National Aeronautics and Space Administration, and the Aerospace Medical Association. Trends shown in the research are a praise of the potential and initial successes of use, but a limitation of the bandwidth (whether through cost or type of equipment used) restricted the full extent of the capabilities. This was particularly true for the telemedicine systems that were connected via satellite. Systems that had little or out-of-date information published about them were not considered for this investigation. Telemedicine systems that were obviously not mobile enough to rapidly deploy with the CF were also not considered. Regardless of the telemedicine system, there are multiple sources that would be involved in determining the handling of telemedicine information within the Department of National Defence information infrastructure. The costs of routing that information from the satellite ground station of a deployed CF contingent to the appropriate medical base or hospital, and the technical guidance required to implement the physical connecting and routing of such a system will not be addressed in the context of this study.

Sources

The Global Forum on Telemedicine. This is normally held every year and includes nations from all over the world. The Department of Defense Telemedicine Test

Bed Board of Directors and the Commanding General of the US Army Medical Research and Material Command host this forum. The proceedings from the forum from May 2000 in Phoenix Arizona have been researched as well as the proceedings from previous years. These proceedings include interviews, briefings and the latest in technology, methodology and practices from around the world.

The Department of National Defence Canadian Military Satellite Communications Project. Both the Canadian Military Satellite Communications Project and the Directorate of Telecommunications and Spectrum Engineering Services located in Ottawa, Ontario, Canada are involved in civilian and military satellite communications for the CF. Their expertise in requirements, engineering and interfacing of equipment would be used to verify and eventually test the satellite communications portion and the pathway routing of the telemedicine information for any Canadian Forces telemedicine equipment.

Telesat Canada and Stratos. They have been very helpful in providing commercial satellite communications test lab facilities, information and contracting assistance. Both companies work with the Canadian Department of National Defence. Telesat Canada also provides the satellite communications technical assistance for several civilian telemedicine networks in rural Canada. The use of these and other commercial companies helps provide the latest in the industry information and are willing to share their worldwide expertise with the Canadian Forces.

The Fort Gordon Battle Command Battle Lab. The lab at Fort Gordon in Augusta, Georgia is focused on telemedicine as one of their command and control

information projects. Multiple trials have been conducted with telemedicine imagery. The focus of the battle lab projects will have not have an immediate impact on a worldwide deployable Canadian Forces system, but will be noted for further development with military terrestrial communications and military satellite communications systems.

Requirements for a CF Telemedicine System

The requirements for a CF telemedicine system are based on a meeting between the investigator and the Deputy Director General of the Defence and Civil Institute of Environmental Medicine (DCIEM) held on 23 November 2000 in Toronto, Canada. The National Defence Headquarters' guidance based on the Special Committee on Medical Review (a Canadian national level in-depth research of issues and priorities in the military medical community) is "Telehealth capability from point-of-injury through to all higher levels of health care elements and units." As part of a Canadian "Revolution in Military Medical Affairs" a project called the Canadian Forces Health Information System (CFHIS) had just received Canadian Department of National Defence approval for further development and funding. The CFHIS involves patient care and support, health care planning and evaluation, and administration to include a full system of electronic health records with three phases to be implemented over five years starting in 2001 with a delivery date of 2008. The Deputy Director General of DCIEM advised that the telemedicine system recommendation from this paper does not have to have the CFHIS requirements as a current criteria but a future system will. As a result of the Deputy Director General's guidance and the CFHIS time line, it was determined that the requirements for a telemedicine system for the CF would be

addressed in two phases. The subject of this paper is the telemedicine system that will meet the requirements for the first phase.

The requirements the telemedicine system must support are:

Consulting (Voice). This is the ability to support a voice recognizable telephone call to and from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement.

Electrocardiogram Reading (EKG) (Fax or Scanned). This is the ability to send and receive an EKG, (abbreviated as ECG in Canada) from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement.

Digital Radiographic Transmission. This is the ability to send a digital image of an X-ray from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The resolution of the transmitted X-ray image is very important for the requested radiologist based in Canada to opine. It is preferable if the system can produce and transmit radiology images of 2,000 by 2,000 pixel clarity for medico-legal opining of X-rays. Greater resolution is more preferable.

Dermatology. This is the ability to send a digital image of a dermatology case from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The resolution of the transmitted image is very important for the requested dermatologist based in Canada to opine.

Transmission Path. The telemedicine system must have the ability to be shift from a satellite link to a terrestrial link if or when available. A higher data rate is preferable to a lower data rate whether on a satellite link or when placed on a terrestrial link from a satellite link. The measurement is in kilobits per second.

Additional requirements are:

Real-Time Video. Real-time video is not required for Phase I of the CF telemedicine system and therefore is not a requirement for systems that will be compared. The taking of a high-resolution picture digitally and then transmitting it (store and forward) is acceptable.

Response Time. The response time from a Canada-based hospital to a deployed unit requesting specialist assistance must be within four hours. The response does not have to be the medical specialist's complete researched answer (i.e., diagnosis or treatment) but must acknowledge receipt of the request and provide interim guidance.

Canada Based Hospital. For the purposes of planning, the Department of National Defence will be structured as a having a Canada-based community level hospital(s) that can support domestic and deployed operations.

Telemedicine Systems Studied

The research conducted for this study was limited to systems that had information published about them in English, were currently being successfully used, and met the initial CF telemedicine requirements. A wealth of research, experimentation, and development was found in the course of this investigator's research, but these particular sources will be recommended for areas of additional study for Phase II of the Canadian

telemedicine requirement. The sources to be investigated further are in accordance with the CF requirements. A description of the systems that met all initial criteria follows. Systems and how they will be abbreviated in this paper are: The US Department of Defense Special Medical Augmentation Response Team Medical Command, Control, Communications, Telemedicine Very Small Aperture Terminal System (MC3T-VSAT), The US Department of Defense Special Medical Augmentation Response Team Medical Command, Control, Communications, Telemedicine (MC3T)¹, and the UK Defence Medical Service Telemedicine Unit, (DMS).

The US Department of Defense Telemedicine Systems

The Telemedicine and Advanced Technology Research Center (TATRC) at Fort Detrick, Maryland, is the technical center for the US Army's Special Medical Augmentation Response Teams (SMART) including Medical Command, Control, Communications and Telemedicine (MC3T). The Director of the Telemedicine Directorate at Walter Reed Army Medical Center Colonel R. Poropatich, and his team leaders at TATRC have been very helpful in providing briefings and after-action reports on the deployed operations they participated in. TATRC currently has and uses two types of deployable telemedicine suites that may be adaptable to CF requirements. The first type for comparison is used for deployments over thirty days. The second type of system to be compared is used for deployments of less than thirty days or where weight and transportation at the deployed location is a factor.²

System One: MC3T-VSAT

The TATRC has recently contracted with Hughes Global Services for the Hughes DemandNet VSAT service with eleven terminals and one year of service. The intent of the service is the transfer of medical records and X-rays and the ability to teleconference.³ The Hughes Global Services system supplies worldwide communications via the PanAmSat global satellite constellation and ground gateways, including use of fiber backbone, the Internet, public-switched telecommunications network access and VSAT terminals.⁴

The US Army wants bandwidth delivered on demand at rates of 64 kilobits per second up to 1.544 megabits per second (known as T-1), depending on the number of satellite ground terminals in the network and each location's bandwidth requirement. Of the eleven portable VSAT terminals purchased, two are C-band and nine are Ku-band space communications satellite ground terminals.⁵ C and Ku band are portions of the super high frequency (SHF) segment of the radio frequency spectrum. The Ku-band terminals give higher data rates with smaller antennas. Ku-band does not cover Africa, South America, and the oceans; therefore two C-band terminals are for those areas. The MC3T-VSAT system would be deployed to a mature theater (a theater of operations where the SMART would be requiring telemedicine support for over thirty days).⁶ The 2.4 meter antenna dish MC3T-VSAT antenna and terminal, bundled for transport weigh approximately 1054 kilograms.⁷ The great weight of the terminal is based on an assumption of a forklift being present at any location in the mature theater the equipment would be deployed to. The VSAT terminal satellite dishes are 2.4 meters in diameter,

with 1.8 and 3.8 meter dishes available for use if required.⁸ Six of the eleven VSAT terminals will be deployed to Bosnia to support military hospitals there, allowing the US Army to use voice, high-speed data, Ethernet and Integrated Services Digital Network services. The system will not only let soldiers in the field send and receive medical data, such as patient records and X-rays, but also let doctors in the field consult with physicians and medical experts in distant medical facilities via teleconferences.⁹ Training for the MC3T-VSAT system is conducted as a four-phase course that is sixteen hours long for those with information system experience. The four phases are theory, classroom review of manuals and procedures, hands-on installation, and problem solving and troubleshooting.¹⁰ Figure 1 shows the satellite ground terminal equipment (modem, controller, and multiplexer mounted in a shock mounted transit case)¹¹ and antenna.



Figure 1. MC3T-VSAT Ground Terminal Equipment and Antenna. Source: Photographs courtesy of David Kelly, Director Field Satellite Services, Hughes Global Services.

The Hughes DemandNet satellite network service is flexible. The network bandwidth can be reallocated, expanded, or moved within the PanAmSat global satellite system on an as-needed basis. The US Army would call DemandNet's Bandwidth Management Controller Center to change the bandwidth quantity, distribution, and location. In addition to the VSAT terminals, Hughes will provide system engineering, integration, installation, training, maintenance and a help desk. Figure 2 shows the Ku and C band global coverage of the system. Coverage of the northern latitudes above sixty-five degrees north such as northern Canada and Greenland may be possible using a PanAmSat satellite that is in an inclined orbit, an orbit that has its footprint of coverage focused on a northern latitude polar region.¹²

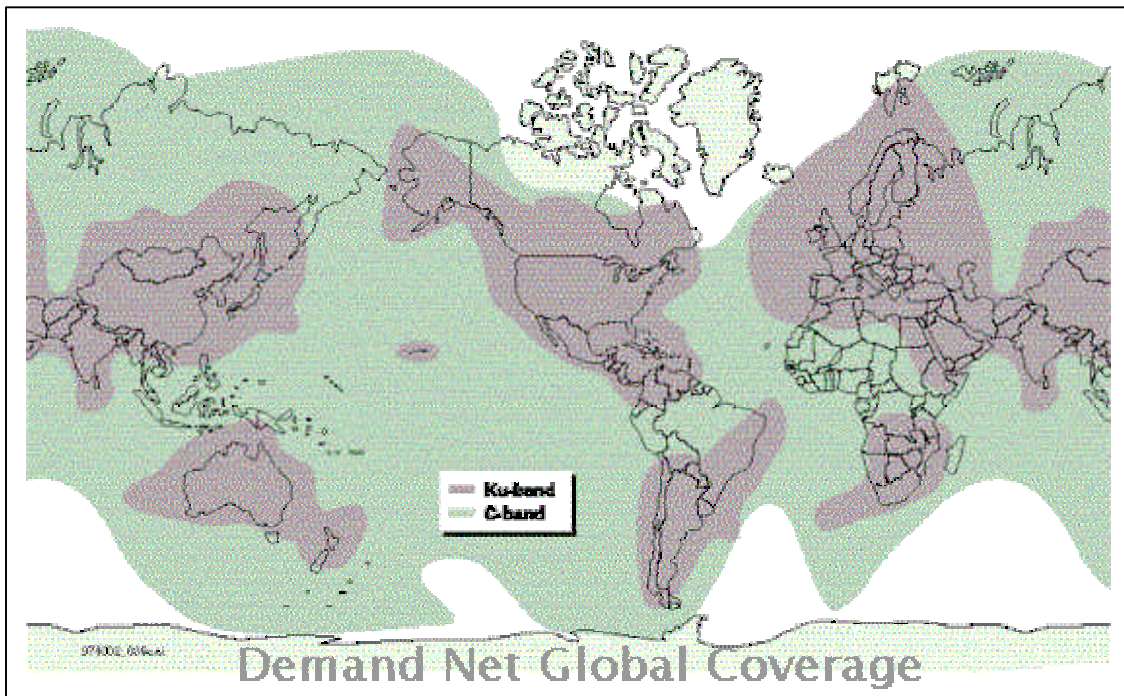


Figure 2. PanAmSat's DemandNet C and Ku band Coverage. Source: Hughes Global Home page, 3 March 2001, Internet

The US Army is using the system through the PanAmSat 1 satellite for communications on the East Coast of the United States. For Europe, such as deployment to Germany and Bosnia, the system will go through PanAmSat 3. The PanAmSat 2 satellite covers the Pacific Ocean region if the US Army requires its use there.¹³

PanAmSat Corporation, based in Greenwich, Connecticut, provides global video and data broadcasting services via satellite. The company builds, owns, and operates networks that deliver entertainment and information to cable television systems, TV broadcast affiliates, direct-to-home television operators, Internet service providers, telecommunications companies, and corporations. With twenty-one spacecraft in orbit, PanAmSat has the world's largest commercial geostationary satellite network.¹⁴

System Two: The MC3T

The TATRC also has a second version of a telemedicine system. The Special Medical Augmentation Response Team (SMART) uses this equipment during a mission to provide short-term medical augmentation to disaster, civil military actions, humanitarian, and emergency incidents. The SMART has been deployed around the world since 1993 to include the Balkans, Haiti, Ivory Coast, Korea, Kuwait, and Somalia.¹⁵ The MC3T equipment comes in three hard shell cases, is transportable by three personnel and fits onto a standard cargo pallet on military aircraft. It weighs a total of 53 kilograms (112 pounds without the generator), costs approximately \$53,000, and takes up .17 cubic meters (6 cubic feet).¹⁶ In Bosnia last year (1999), the Army used eleven MC3T Inmarsat terminals for an average of ten minutes per day at sixty-four kilobits per second.¹⁷ A brief description of the Inmarsat satellite system will follow the

descriptions of the MC3T and DMS. Both telemedicine systems use Inmarsat as their satellite communications pathway.

The MC3T system consists of the following equipment¹⁸:

1. Nera INMARSAT “B” satellite communications terminal with a 64 kilobit per second capability, shown in Figure 3

2. Pentium based Dolch computer with PictureTel PCS50 video cards

3. Nikon Coolpix 950 with 2.11 megapixel resolution, images saved in uncompressed TIFF or one of three JPEG compression modes and an eight Megabyte CompactFlash memory card¹⁹; and other digital cameras as required

4. Multiple types of imaging scopes including a dermatology scope, ent/ophthalmoscope by AMD and dental scope by Air Techniques and a Canon L-2 video camera

5. Microsoft Word, Powerpoint and Excel with Adobe Photoshop for image compression, filemaker pro for medical consults and Eudora for store and forward image transmissions

6. Uninterruptible Power Supply (UPS)

7. Zydacron V.35 interface card

8. Audio and Video capture board

9. Gas powered generator

10. A supporting hospital with specialists located at Walter Reed Army Medical Center (AMC), Washington, D.C., as well as specialist bases at Eisenhower AMC, Augusta, Georgia; Brooke AMC, San Antonio, Texas; Madigan AMC, Tacoma,

Washington; Tripler AMC, Honolulu, Hawaii; and Landstuhl AMC, Landstuhl, Germany.²⁰



Figure 3. SMART Team Satellite Terminal with Video Teleconference Capability. Source: Photograph courtesy of the Telemedicine & Advanced Technology Research Center.

System Three: The Defence Medical Services Telemedicine Unit

The Defence Medical Services (DMS) Telemedicine Unit is at the Royal Hospital Haslar, Gosport, United Kingdom. Members of this unit have developed and used a portable telemedicine system in Bosnia, Belize, Kosovo, Sierra Leone, and the South Georgia Islands. The DMS system is based solely on the store and forward transmission of still digital images attached to electronic mail containing clinical information on the patient's case and are transmitted using straightforward protocols.²¹ The store and forward telemedicine system included the development of software for receiving, archiving, and replying to electronic mail referrals.²² The DMS system weighs a total of

38 kilograms (83.6 pounds), costs approximately \$24,500, and takes up approximately .15 cubic meters (5.3 cubic feet).

The DMS System consists of the following:

1. Nera Saturn Bt INMARSAT Satellite communications terminal with a 64 kilobit per second capability
2. Olympus C1400L still digital camera with 1.4 megapixel resolution, three times single lens reflex (SLR) zoom lens, with images saved in JPEG baseline mode and a two times four megabyte card.²³ (The DMS would ideally use a camera with 2.5 megapixels, single lens reflex (SLR) capable, and have a screw fitting capable of adding further macro filters for close up photography)
3. Tripod (used when taking photos of X-rays on a viewing box or with microscopes)
4. Rock Mentor 620 Pentium 200 Megahertz computer with a thirteen-inch screen, forty-eight megabyte random access memory and two gigabyte hard drive (a laptop is better for doctors on the move, a desktop where conditions are more static)
5. Email account with a store and forward transmission of text and images
6. Telephone and modem
7. A network of hospital specialists based at the Royal Hospital Haslar, Gosport, United Kingdom.

The DMS uses specially developed software for receiving, archiving, and replying to electronic mail referrals. The software is called Tmed2000, developed for Windows and Linux operating systems and is freely available.²⁴

Where possible ordinary telephone lines are used to minimize cost, but satellite telephones are used on board ship and in war zones such as Bosnia Herzegovina and Kosovo.²⁵ Figure 4 shows the DMS system components of the laptop computer, X-ray viewing box and Olympus camera with tripod.



Figure 4. DMS System showing digital camera, viewing box and computer. Source: Photograph courtesy of LCol David J Vassallo, Defence Medical Services Telemedicine Unit.

Information on the INMARSAT Satellite System

Inmarsat based in London, United Kingdom, operates a global satellite system used by independent service providers to offer a range of voice and multimedia communications for land, mobile, and aeronautical customers on the move or in remote locations.²⁶ Depending on the type of terminal used, services available include direct-dial telephone, data, facsimile, telex, electronic mail, high quality audio, compressed video

and still video pictures, telephoto, slow-scan television, videoconferencing, and telemedicine.²⁷

The Inmarsat satellite coverage is divided into four ocean regions (figure 5), covering every corner of the globe apart from the extreme poles. Each region is covered by an Inmarsat satellite and its operational spare. Each satellite's global beam covers roughly one-third of the Earth's surface. Every satellite has its antennas and electronics tuned for optimum coverage of a particular area on Earth, known as its footprint.²⁸

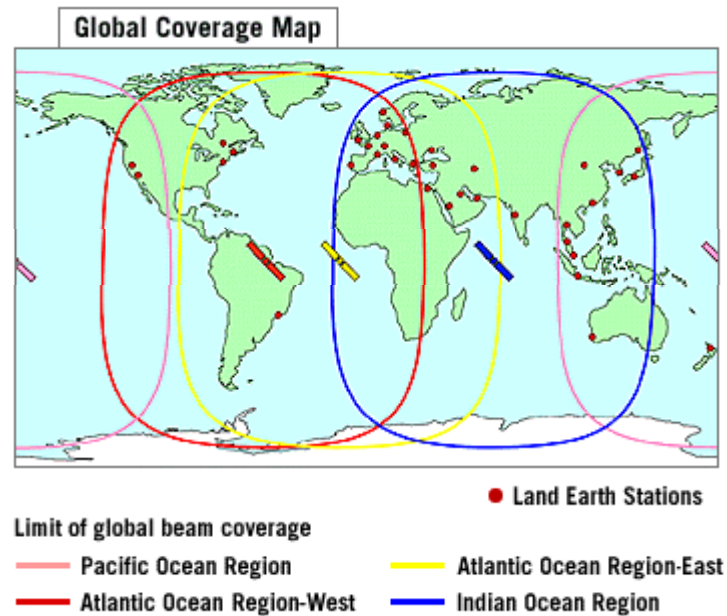


Figure 5. INMARSAT Satellite Network Coverage. Source: Inmarsat Home Page, 6 December 2000; Internet.

The purpose of this paper is to conduct an exploratory descriptive analysis of existing systems to identify three or more that will best suit the CF needs and then to do a comparative analysis in order to recommend a telemedicine system that the CF can implement and deploy with. Three systems, (MC3T-VSAT, MC3T, and DMS) have been identified and will be compared in chapter 4. Chapter 3 will define the individual requirements that all systems must meet. By meeting the requirements each system will answer the research question and subordinate questions as stated.

Research Questions

Primary Question: What is a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada based supporting hospital?

Subordinate Question Set 1: What is the requirement in deliverable medical

service? What is the bandwidth that the CF require? Will there be a baseline of medical service required for every mission? Does the CF medical community need the telemedicine service capability to be expandable to include additional services?

Subordinate Question Set 2: Are there other systems currently in use that the Canadian Forces can use? Is the US DOD deployable telemedicine model valid for application to the CF? Is there a way to piggyback or dovetail with the US DOD in either terminal equipment or satellite bandwidth?

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¹Tommy Morris, Senior Systems Analyst, Medical Advanced Technology Management Office, Fort Detrick, Maryland; interview by electronic mail to this investigator; 9 March 2001.

²Morris.

³John Williamson, "Jane's Military Communications 1998-1999." [On-line] Available from [http://www.janes.com/defence/market_review .../military_communications_1998-1999_02.shtml](http://www.janes.com/defence/market_review.../military_communications_1998-1999_02.shtml); Internet: accessed 25 September 2000.

⁴Gregory Slabodkin, "VSATs supply global sky links," *GCN*, 23 February 1998; [On-line] Available from <http://www.gcn.com/archives/gen/1998/February23/dod.html>; Internet; accessed 6 December 2000.

⁵Morris.

⁶Morris.

⁷David Kelly, Field System Services, Hughes Global Networks; interview by electronic mail to this investigator, 6 March 2001.

⁸Slabodkin.

⁹Ibid.

¹⁰Kelly.

¹¹Kelly.

¹²Slabokin.

¹³Ibid.

¹⁴PanAmSat Home Page, "Company Overview"; [On-line] Available from <http://www.panamsat.com/comp/company.html>; Internet: accessed 6 December 2000.

¹⁵Ronald K. Poropatich, Colonel, USA, Director Telemedicine Directorate, Walter Reed Army Medical Center and Director Clinical Applications Division, Telemedicine & Advanced Technology Research Center, Fort Detrick, Maryland. briefing presentation given to this investigator on 27 February 1998.

¹⁶Ibid.

¹⁷Slabodkin.

¹⁸Morris. "Telemedicine in Support of Operations in Remote Locations." Abstract sent by email to this investigator, 9 March 2001.

¹⁹Nikon Home Page, "Digital Cameras Coolpix 950" [On-line], Available from http://www.nikonusa.com/usa_product/product.jsp?cat=1&grp=2&productNr=25043; Internet: accessed 26 March 2001.

²⁰Poropatich.

²¹LCol David J Vassallo, Defence Medical Services Telemedicine Unit, Royal Hospital Haslar, Gosport, Hants, PO 14 2DL, UK; interview by electronic mail to this investigator, November 2000.

²²Ibid.

²³Olympus Home Page, "C-1400L Specifications" [On-line], Available from <http://cf.olympus-europa.com/consumer/digimig/hall/cameras/C1400L/spec.stml>;

Internet: accessed 26 March 2001.

²⁴Ibid.

²⁵Ibid.

²⁶Inmarsat Home Page, [On-line], Available from <http://www.inmarsat.org/about>; Internet: accessed 6 December 2000.

²⁷Ibid.

²⁸Ibid.

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CHAPTER 3

RESEARCH METHODOLOGY

In order to answer the primary question: What is a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada-based supporting hospital? the investigator conducted an exploratory descriptive analysis of three existing systems that will be compared to best fit the CF requirements. The three telemedicine systems identified met all Phase I criteria and will be measured against the CF requirements. Those not meeting all criteria were excluded from the comparison, but are included in the recommendations for further study in preparation for Phase II of the CF telemedicine system.

The Canadian National Defence Headquarters' guidance for a telemedicine system was based on a national level in-depth research of priorities in the medical community called the Special Committee on Medical Review. The statement from this review was "Telehealth capability from point-of-injury through to all higher levels of health care elements and units." The investigator and the Deputy Director General, Defence and Civil Institute of Environmental Medicine (DCIEM) further refined the broad mandate given on 23 November 2000 at a meeting held in Toronto, Canada, at DCIEM. As part of a Canadian "Revolution in Military Medical Affairs" a project called the Canadian Forces Health Information System (CFHIS), had just received approval for further development and funding. The project is a fully automated system of all CF members' electronic health records with a delivery date in 2008. The Deputy Director General stated that the telemedicine system recommendation does not have to have the

CFHIS requirements evaluated under the criteria, but a future system will. The investigator determined to address the issue of requirements in two phases based off of the CFHIS timeline. This investigation is Phase I of the CF telemedicine requirements. In addition to the medical capability requirements several deployable satellite ground terminal requirements are used to further define each compared system. Phase II must be able to carry CFHIS information and will be the subject of future study. As mentioned in chapter 2, the requirements the telemedicine system must support are:

Consulting (Voice)

This is the ability to support a voice recognizable telephone call to and from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. Toll quality is better than voice recognition. Toll quality is what one expects to hear when using a telephone at home, voice recognition is where the speaker knows whom they are speaking with, but there is background noise or minor interruptions in the audible clarity of the telephone conversation. Measurement is voice quality. Increased voice quality is more acceptable to decreased voice quality. The standard of quality in voice telephony is “toll quality,” the voice quality expected from a normal landline telephone.

Electrocardiogram Readability (Fax or Scanned)

This is the ability to send and receive an electrocardiogram (EKG), (abbreviated as ECG in Canada) from a deployed CF medical health care provider to a medical

specialist based in Canada. This capability does not need to be simultaneous with any other requirement. Measurement is visual clarity. Increased visual clarity is more acceptable to decreased visual clarity.

Digital Radiographic Transmission

This is the ability to send a digital image of an X-ray from a deployed CF medical care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The resolution (clarity) of the transmitted X-ray image is very important for the requested radiologist based in Canada to opine. It is preferable if the system can produce and transmit radiology images of 2,000 by 2,000 pixel clarity for medico-legal opining of X-rays. Measurement is resolution. Higher resolution (therefore providing a better picture) is preferable to lower resolution.

Dermatology

This is the ability to send a digital image of a dermatology case from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The clarity of the transmitted image is very important for the requested dermatologist based in Canada to opine. Measurement is image resolution, and this criterion will be measured as part of digital radiographic transmission.

Transmission Path

The telemedicine system must have the ability to be shifted from a satellite link to a terrestrial link if or when available. Measurement is data rate. A higher data rate is preferable to a lower data rate whether placed on a terrestrial link from a satellite link.

Space Segment Potential for Increase

Requirements are not completed for a Phase II telemedicine system for the CF however, all indicators are that the requirements will need more bandwidth. The space segment each system uses were compared with how each telemedicine system can increase the bandwidth it can use with the current evaluated space segment. Measurement is the ability to increase bandwidth use without adding additional communication equipment is preferable.

Training Required to Operate

Systems were compared by how much estimated training time is required to learn and set up the system. Training times will be acquired from the current users of the system. Measurement is training time in man-hours, less time is preferable.

Weight and Cubic Size Using Metric System Units

Weight and cubic size were divided into two categories, medical equipment and communications equipment. Less weight and less cubic size are preferred.

Measurements are weight and cubic size. Cost in Current U.S. Dollars

Costs were separated into space segment (how much the satellite links cost), medical specific equipment and communications and satellite ground terminal equipment.

Measurement is that the lower cost is preferred.

Additional Requirements Not Used as Criterion for Comparison Real-Time Video. Real-time video is not required for Phase I of the CF

telemedicine system and therefore was not a requirement for the systems compared. The taking of a high-quality picture digitally and then transmitting it (Store and Forward)

is acceptable.

Response Time. The response time from a Canadian based hospital to a deployed unit requesting specialist assistance must be within four hours. The implication is not to necessarily have the medical specialist's answer (i.e. diagnosis and treatment), but to acknowledge the request and give interim guidance. This requirement is the responsibility of the CF.

Canada-Based Hospital. For the purposes of planning, the Department of National Defence will be structured as a Canada-based community-level hospital.

This requirement is the responsibility of the CF.

Comparison Table

A table of criteria is shown at table 1. The Canadian Forces Defence and Civil Institute of Environmental Medicine reviewed the criteria and the comparison

methodology. The criteria are not listed in order of importance and no weight was applied to the criteria. No criteria were weighted so that the CF can select the most important criteria and determine the best system or best elements of a system that meet their requirements in accordance with those chosen weighted criteria. The values are in the unit of measurement (dollars, voice quality, data rate, etc.) used. Table 1 shows the overall evaluation framework. A numerical evaluation using +1, 0, -1 will be used to compare the systems. The plus one (+1) is used where one system measured better than other two in that criterion. Zero (0) is used if two systems were the same or is used to denote the median of difference between the three systems. The minus one (-1) is used for a system that meets the relative criterion the least. Each criterion for each system will be assigned a +1, 0, or -1 and all compared system criterion scores will be summed for a compared system overall score. The overall score for each system will show which system meets the overall criteria from best to least when no criteria are weighted.

CHAPTER 4

ANALYSIS OF TELEMEDICINE SYSTEMS

Answering the primary question: What is a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada based supporting hospital? required an exploratory descriptive analysis of three existing systems that were compared to best fit the CF requirements. The telemedicine systems identified in chapter 3 have met all Phase I criteria and were measured against the CF requirements. Those not meeting all criteria were excluded from the comparison. The results of the comparison of the three systems in regard to the required criteria follow.

Consulting (Voice)

This is the ability to support a voice recognizable telephone call to and from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. Toll quality is better than voice recognition. Toll quality is what one expects to hear when using a telephone at home; voice recognition is where the speaker knows to whom they are speaking with, but there is background noise or minor interruptions in the clarity of the telephone conversation. Measurement is voice quality. Increased voice quality is more acceptable to decreased voice quality. The MC3T-VSAT provides toll quality voice on

one to two voice links as currently configured. The MC3T and DMS provide voice recognition to toll quality voice on one voice link only as currently configured.

Electrocardiogram Readability (Fax or Scanned)

This is the ability to send and receive an electrocardiogram (EKG), (abbreviated as ECG in Canada) from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. Measurement is visual clarity. Increased visual clarity is more acceptable to decreased visual clarity. All three systems provide the same visual clarity based on satellite system capability. Specific fax or scanning capabilities of different equipment was dependent on the particular fax or scanner used. All three systems can equally support EKG reading clarity, meeting the CF requirement.

Digital Radiographic Transmission

This is the ability to send a digital image of an X-ray from a deployed CF medical care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The resolution of the transmitted X-ray image is very important for the requested radiologist based in Canada to opine. It is preferable if the system can produce and transmit radiology images of 2,000 by 2,000 pixels for medico-legal opining of X-rays. Measurement is resolution. Increased resolution (therefore providing a better picture) is preferable to decreased resolution. The MC3T-VSAT and MC3T systems have a Nikon Coolpix 950 digital camera that has 2.11 megapixel resolution. The DMS system uses an Olympus C1400L digital camera that has a 1.41 megapixel resolution capability.

Dermatology

This is the ability to send a digital image of a dermatology case from a deployed CF medical health care provider to a medical specialist based in Canada. This capability does not need to be simultaneous with any other requirement. The resolution of the transmitted image is very important for the requested dermatologist based in Canada to opine. Measurement is resolution and will be measured as part of the digital radiographic transmission criterion.

Transmission Path

The telemedicine system must have the ability to be shifted from a satellite link to a terrestrial as available. Measurement is data rate. A higher data rate is preferable to a lower data rate whether on a satellite link or when placed on a terrestrial link from a satellite link. The MC3T-VSAT provides bandwidth from sixty-four kilobits per second up to 1.544 megabits per second (T-1). The MC3T and the DMS system provide bandwidth up to sixty-four kilobits per second.

Space Segment Potential for Increase

Requirements are not completed for a Phase II telemedicine system for the CF; However, all indicators are that the requirements will need more bandwidth. The space segment each system uses was compared with how each telemedicine system can increase the bandwidth it can use with the current evaluated space segment. Measurement is the ability to increase bandwidth use. Increase of bandwidth without adding additional communication equipment is preferable. The MC3T-VSAT can be configured in

coordination with the DemandNet operations center up to T-1 for any of the terminals in the network, (with an impact of decreasing the bandwidth to the other terminals). The capability exists with the current MC3T-VSAT equipment to increase the bandwidth to two megabits per second. The MC3T and the DMS systems may be able to take advantage of the current INMARSAT technology being fielded to increase the bandwidth by 64 kilobits per second, bring the overall capability of either system to 128 kilobits per second.

Training Required to Operate

Systems were compared by how much estimated training time is required to learn and set-up the system. Training times were acquired from the current users of the system and from the investigator's personal experience. Measurement is training time in man-hours, less time is preferable. The MC3T-VSAT requires sixteen man-hours of training for information system experienced personnel (longer for those with no information system experience) and is conducted in four phases. The MC3T requires eight hours and the DMS system requires six hours.

Weight and Cubic Size using Metric System Units

Weight and cubic size were divided into two categories, communications and medical equipment weight, and communications and medical equipment size. Less weight and less cubic size is preferred. Measurements are weight in kilograms (kg) and

cubic size in square meters (m³). Table 2 displays the weight and cubic size of each system.

Table 2. Compared Systems Communications and Medical Equipment Weight and Size

MC3T-VSAT	1107 kilograms	8.42 cubic meters
MC3T	53 kilograms	.17 cubic meter
DMS	38 kilograms	.15 cubic meter

Cost in Current US Dollars

Costs were separated into space segment (how much the satellite links cost), medical specific equipment and communications and satellite terminal equipment.

Measurement is cost is current US dollars with lower cost being preferable. The costs of the medical and communications terminal equipment are directly comparable.

MC3T-VSAT and MC3T medical equipment and peripheral communications equipment cost \$53,000. The DMS system's medical equipment and communications equipment cost \$48,000. The space segment costs are not directly comparable as it is a comparison between a lease for an amount of bandwidth over a period of time for the MC3T-VSAT and a per minute charge rate for the MC3T and DMS system using Inmarsat. The space segment for the MC3T-VSAT is divided into separate costs for C band and Ku band. A 2.4-meter antenna C-band system at 256 kilobits per second will range from \$3,837 to \$5,756 per month. A 1.544 megabits per second C-band system will range from \$22,257

to \$33,386 per month. A 2.4-meter antenna Ku-band system at 256 kilobits per second will range from \$4,797 to \$7,196 per month. A 1.544 megabits per second system will range from \$27,825 to \$41,738 per month. It must be noted that the monthly prices for space segment are capable of sharing that bandwidth with more than one terminal. Costs for Inmarsat use are from four to nine US dollars per minute for Inmarsat service. The example of use given for an Inmarsat terminal deployed in Bosnia was ten minutes of use per day. Ten minutes per day for thirty days at an average of \$6.50 per minute for one terminal would cost \$1950 per month. For the purposes of this study, the median cost of a 256 kilobits per second for a C-band system (as C-band has more global coverage) will be used for the MC3T-VSAT system at \$4,796 per thirty-day month and the median value of \$6.50 per minute will be used for the MC3T and DMS systems per thirty day-month.

Additional Requirements Not Used as Criterion for Comparison

Each system in respect to these requirements will be addressed. The ability to fulfill a future requirement for Phase II of a CF telemedicine system will be the focus of the answer.

Real-Time Video. Real-time video is not required for Phase I of the CF telemedicine system and therefore was not a requirement for the systems compared. The taking of a high-quality picture digitally and then transmitting it (store and forward) is acceptable. Current bandwidth requirements for real-time video require systems that are normally supported at a minimum of 384 kilobits per second. Advances in data compression and other technological advances may decrease the amount of bandwidth

required and will need to be studied for Phase II. Currently even with space segment potential for increase, only the MC3T-VSAT system is capable of meeting this requirement.

Response Time. The response time from a Canada-based hospital to a deployed unit requesting specialist assistance must be within four hours. The implication is not to necessarily have the medical specialist's answer (i.e., diagnosis and treatment), but to acknowledge the request and give interim guidance. Although each system's bandwidth and transmission time would effect how fast a deployed specialist could request assistance, this response time is based off of when a request is received at a Canada-based hospital. This requirement is primarily a procedural responsibility of the C F and is outside of the scope of this study.

Canada-Based Hospital. For the purposes of planning, the Department of National Defence will be structured as having the support of a Canada-based community-level hospital. The MC3T-VSAT system could be tied into a satellite ground station hub or the civilian telecommunications network and connected to telecommunications system of the Canada-based hospital. The MC3T and DMS systems using Inmarsat can dial into the civilian telecommunications systems or another Inmarsat. This requirement is the responsibility of the CF and Government of Canada to determine the location of this hospital and is outside the scope of this study.

Telemedicine System Comparison Table

A table of criteria with values for how each compared system met the criteria is shown at table 3. The Canadian Forces Defence and Civil Institute of Environmental Medicine reviewed the criteria and the comparison methodology. The criteria are not listed in order of importance and no weight was applied to the criteria. No criteria were weighted so that the CF can select the most important criteria and determine the best system or best elements of a system that meet their requirements in accordance with those chosen weighted criteria. The values are in the unit of measurement (dollars, voice quality, data rate, etc.) used. A numerical evaluation using was used to compare the systems. The plus one (+1) was used where one system measured better than the other two in that criterion. Zero (0) was used if two systems were the same or was used to denote the median of difference between the three systems. The minus one (−1) was used for a system that meets the relative criterion the least. Each criterion for each system was assigned a +1, 0, or −1 and all compared system criterion scores were summed for a compared system overall score. The overall score for each system showed which system met the overall criteria from best to least when no criteria were weighted.

Research Questions

Primary Question: What is a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canadian-based supporting hospital?

Answer: Of the three systems analyzed (MC3T-VSAT, MC3T, and DMS), all are viable since they met all criteria. The purpose of assigning a scored value was to relate a common base of comparison between the systems with all evaluative criteria being equal. The determination of which system would best meet the requirement would be based on the CF determining which criteria are the most important and should be weighted in a comparison.

The MC3T-VSAT scored a cumulative zero (0). The MC3T-VSAT system could support one more telephone line than any other system as currently configured and has a

Table 2. Telemedicine Systems Evaluated Against Criteria

See File “Table 2 Measured Against Criteria V2”

digital image resolution of 2.11 megapixels. The MC3T-VSAT has much greater transmission path bandwidth, up to 1.544 megabits per second versus 64 kilobits per second for the other two systems, and greater space segment potential increase up to 2 megabits per second. However, the MC3T-VSAT system takes more time to train up on (eight more hours than the other two systems) particularly if inexperienced information systems personnel are being trained, costs more (almost \$3,000 more than the MC3T and \$33,300 more than the DMS system), and weighs over 1000 kilograms more than the other two systems.

The MC3T scored a cumulative zero (0). The MC3T can support one telephone line and has the same digital image resolution capability as the MC3T-VSAT system since it uses the same type of digital camera. The MC3T has the same bandwidth (64 kilobits per second) and space segment potential increase (128 kilobits per second) as the DMS system. The MC3T system is 15 kilograms heavier and \$30,500 more expensive than the DMS system.

The DMS system scored a two (2). The DMS system has the same consulting capability of one voice telephone line as the MC3T system, has a digital camera with the least amount of resolution at 1.41 megapixels, and has the same bandwidth and space segment potential increase as the MC3T system. The advantage to the DMS system is that it takes less time to train on (6 man-hours), weighs the least (38 kilograms), and costs the least (\$24,500) of the three systems.

Subordinate Question Set 1:

- a. What is the requirement in deliverable medical service?

Answer: The current requirements of consulting capability, electrocardiogram (EKG/ECG) readability, and digital radiographic imagery (with dermatological imagery included in this category for comparison purposes) were met by all systems. The CF will have to reevaluate the requirements in deliverable medical services and satellite or communications system needs before CFHIS is fielded in 2008. This investigator has limited the scope of the paper to a system that could support the current CF requirement up to the fielding of CFHIS.

b. What is the bandwidth that the CF require?

Answer: The minimum bandwidth to fulfill current CF requirements is sixty-four kilobits per second. While the ability to conduct voice consulting does not require sixty-four kilobits per seconds and can be accomplished as low as 2.4 kilobits per second, the minimum amount used successfully to transmit imagery in a store and forward capacity in a timely manner provided by worldwide service providers is sixty-four kilobits per second.

c. Will there be a baseline of medical service required for every mission?

Answer: Yes. The requirements of voice consulting, EKG/ECG, digital radiographic imagery, and dermatological imagery are the current Phase I baseline requirements analyzed in this study. The medical service requirement of a four-hour response time for a medical specialist based in Canada to answer a request by a medical specialist in a deployed unit, as well as a Canada-based supporting hospital's location, composition of staff, and twenty-four-and-seven capability were not studied as stated earlier in this paper in Chapter 2.

- d. Does the CF medical community need the telemedicine service capability to be expandable to include additional services? Answer: Yes. The additional requirements for a Phase II telemedicine system will address these expanding requirements as they are developed with a particular focus on the requirements of real-time video and CFHIS. Lessons learned from deployments, use, and integration into the medical community of a Phase I system can be incorporated to make the Phase II system more responsive and accurately reflect the requirements of CF deployed medical specialists.

Subordinate Question Set 2:

- a. Are there other systems currently in use that the Canadian Forces can use?
Answer: Yes. The three systems (MC3T-VSAT, MC3T, and DMS) formed the basis for the comparison of deployable telemedicine systems. These systems are in use providing telemedicine capability on a daily basis for deployed forces of the US and UK. The three compared systems through comparison showed the advantages and disadvantages of a bigger bandwidth, long-term deployment system (the MC3T-VSAT), a lighter but less bandwidth capable system, (the MC3T) and a very light and basic system, (the DMS). Additional systems are used by the US and other nations but were outside the scope of this study because they are not deployable or enough comparative information was not available.
- b. Is the US DOD deployable telemedicine model valid for application to the CF?

Answer: Yes. The two compared US systems are valid. Both systems meet the non-weighted criteria as shown previously in this chapter, giving the CF the ability to choose the most important criteria to draw conclusions on the modeling of a telemedicine system. The US DOD deployable telemedicine model will be of continued interest as CF requirements are examined for the Phase II system. The requirement of a Canada-based hospital will still need to be researched to complete a model validation in comparison with the US DOD model of a deployed SMART with MC3T-VSAT or MC3T and the home-base hospital it is connected to via satellite such as Walter Reed Army Medical Center (AMC), Washington, D.C., or specialist bases such as Eisenhower AMC, Augusta, Georgia; Tripler AMC, Honolulu, Hawaii; and Landstuhl AMC, Landstuhl, Germany.

c. Is there a way to piggyback or dovetail with the US DOD in either terminal equipment or satellite bandwidth?

Answer: The investigator found the US DOD telemedicine personnel willing to discuss with the CF possible contracting coordination or assistance in vendor information. The different methods of payment and contracting may prove contractually difficult to piggyback or dovetail in equipment and bandwidth use from a coordinated purchase without the use of a formal memorandum of understanding. The piggyback or dovetailing of actual service is a possibility where CF and DOD personnel are co-located. The development of a NATO telemedicine standard may be the most viable method for the US, Canada, and other members of NATO to consolidate satellite ground terminal assets and bandwidth capacity.

The results of the comparison are positive and useful. By not weighing the criteria, any factor(s) that the CF deems most important will help determine which system is most viable for their current requirements.

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this paper was to conduct an exploratory descriptive analysis to compare existing deployable telemedicine systems and to identify which of those would best meet the telemedicine requirements of the CF as a viable satellite means for the CF medical community to deliver telemedicine information between a deployed force and a Canada-based support hospital. A comparative analysis was completed in order to recommend a telemedicine system that the CF can implement and deploy with.

All three of the compared and analyzed systems: the MC3T-VSAT, the MC3T, and DMS are viable but no system is clearly better than another with all evaluative criteria being equal. The DMS system had the overall highest score of two (2) by being the lightest, least expensive and easiest to train on but by using the same satellite service provider of Inmarsat, otherwise compares very similarly to the MC3T. The MC3T scored a zero (0), the same score as the MC3T-VSAT, but for very different reasons. The MC3T was the second highest scoring of the three systems compared for training required, weight, cubic size, and cost, being slightly heavier and slightly more expensive than the DMS system, but has slightly more capability with a small video teleconference capability. The MC3T-VSAT also scored a zero (0) because of the average of several distinct advantages with several distinct disadvantages. The MC3T-VSAT system as configured can provide one more simultaneous consulting or EKG transmission capability, has a much greater bandwidth capability and the greatest space segment potential increase, but weighs significantly more, and is the most expensive of the three systems compared in equipment cost and space segment.

It has been shown that all compared systems can meet a neutral (non-weighted) set of criteria by the examination of telemedicine systems that are currently in use, are deployable, and are used to meet similar requirements in the military forces of the US and UK. The strengths and weaknesses of a system, such as cost, weight, and bandwidth, can be compared individually, and the relationship between each category is readily discernible. For the systems compared, it is shown in general terms that increased bandwidth costs more, a bigger bandwidth providing system weighs more, and EKG readability while a requirement for the CF, was not a determinant criteria in any of the compared telemedicine systems.

The advantage to this analysis is that the CF can tailor a satellite delivered telemedicine system that meets their requirements in accordance with their most important criteria or select one of the compared telemedicine systems outright to use as a prototype or baseline system. The CF will also be able to rapidly compare the advantages and disadvantages that any tailored satellite delivered telemedicine system they develop has by using the comparison of systems conducted in chapter 4 and shown in table 2. The format of the comparison can be adjusted as needed or as future requirements dictate. This advantage lends itself in relation to the selected criteria for a current Phase I system or in future development of requirements for a Phase II telemedicine system for the CF.

The Way Forward

As stated in chapter 1, this paper focused on Phase I of a deployable telemedicine system for the CF. A baseline set of requirements were developed, defined and quantified. The same baseline requirements with Phase II additional requirements will

need to be developed in conjunction with the fielding of the Canadian Forces Health Information System electronic health records.

There is a distinct advantage to phasing the telemedicine requirements and the system that meets those requirements. The three requirements that were not used for comparison, real-time video, response time, and a Canada-based supporting hospital must be further investigated and defined by the CF, and solutions can be found before a more complex set of requirements are imposed prior to the development and implementation of a Phase II telemedicine system.

The CF must designate who or what CF unit is responsible for the deployment, installing, operating and maintaining of any satellite delivered telemedicine system. This would include who in the CF has the responsibility for higher-level maintenance, the contracting or leasing of support and the identification of where the funding for the communications systems, training and maintenance comes from. There is time to develop standard operating procedures during and ideally before a Phase I telemedicine system trial or prototype is used.

The CF medical community designation of responsibility would include several areas for the CF medical command structure to plan and develop. The determination of who with national level visibility will be given the authority to task members of the CF medical community with providing the care for deployed CF medical cases, who can rapidly contract that care with civilian medical personnel when CF medical personnel are not available as well as who specifically at what military or civilian hospital will handle those cases will need to be resolved. Additionally, the CF medical community must determine how shift work for a twenty-four-hour-a-day availability is established, how

the medical records will be updated, the development of a core of CF medical area specialists to serve the soldiers, sailors, and airmen of the CF on deployments and the contact procedures to notify those medical area specialists when their expertise is required.

The application of funds to collect data and test proposed systems or to conduct “buy and try” prototype experiments of proposed or CF modified systems can apply the lessons learned from a Phase I system into the development, testing, and implementation of a Phase II system. This should be concurrent with operational procedures development to maximize the benefit to the deployed CF medical element and establish how the Canada-based medical network of medical specialists and medical operations personnel will support that deployed medical team.

The ability to compare what different countries have tried and compare each of their systems strong and weak points is a great advantage, particularly in light of new technologies that will be available. Lighter antennas, cameras with greater resolution, and advantageous use of space segment and bandwidth will not only save weight and money, but also provide better medical service to the deployed forces. Great possibilities for economy in bandwidth usage and in available satellite terminal equipment were found in the conduct of this investigator’s research.

The satellite terminal equipment and space segment provider INMARSAT that the MC3T and DMS systems use is well known within the CF. The CF national-level signal office Directorate of Telecommunications and Spectrum Engineering Services has an office that performs the life cycle maintenance management for Inmarsat terminalequipment for the entire CF. The CF currently has a long-term Inmarsat lease

that is used by deployed CF elements. Further study should be done on a bigger bandwidth satellite system with worldwide coverage, such as that provided by PanAmSat or a similar space segment provider, for an increased bandwidth role. The key to choosing an appropriate satellite service provider is cost of space segment, flexibility to adjust bandwidth from one region of the world to another, the possibility of coverage of the northern Canadian latitudes, and ease of operation. There is benefit in choosing a satellite service provider that other elements of the DND requiring space segment can also use. The combined contracting and buying power to share space segment between different DND elements as well as purchase satellite ground equipment or terminals provides more worldwide flexibility, frequently more bandwidth, and a cost savings over the long term. The larger size and greater bandwidth MC3T-VSAT equipment that TATRC uses meets the requirements of the CF, but mobility would be limited by weight. Several commercial companies including the company that manufactures the terminal equipment for the MC3T-VSAT manufacture similar antenna and satellite transceiver equipment that is much lighter and provides the same capability.

With the development of a CF telemedicine system, the US DOD and CF DND can coordinate critical medical service capabilities on deployments in the future. The additional expertise in satellite system based setup, bandwidth management, and application of technologies is of great benefit when multinational force headquarters and support areas have limited assets and personnel.

The US and Canada are members of the NATO Military Medical Group Subcommittee on Telemedicine. The US has been appointed the custodian for the development of a telemedicine Standard NATO Agreement (STANAG) and chairs the

Telemedicine Subcommittee. This Subcommittee has the responsibility to coordinate for the planning, integration, and standardization of telemedicine systems. With Canada joining the US, UK and others with a fielded telemedicine system, Canada is able to provide field and operationally experienced input and direction along with the US and UK to help shape the future NATO standards. When NATO standards and systems are developed or acquired that meet those standards, the opportunity is present for an even greater use of common telemedicine assets, shared expertise, and timely medical help to the forces.

Relationships to Previous Studies

Telemedicine systems that are currently in use and based off on a satellite system delivery as the primary transmission path are not ground breaking or original in concept. Many nations, medical-oriented businesses, military organizations, and governmental agencies use satellite system provided telemedicine on a daily basis for both mobile and fixed location requirements. However the application of a comparative analysis of existing systems based on the developed CF requirements is new. This investigator found from research, supplemental interviews, and tips, tactics, and procedures via electronic mail, valuable lessons learned from the US and UK on why they selected the systems they did and a general assessment of their performance.

The intent of this study was to show a viable satellite means of delivering telemedicine information between a deployed force and a Canada-based supporting hospital for the CF. At the time of the study the CF had to evacuate a CF member back to Canada, use another nation's telemedicine equipment, or send a doctor or appropriate medical specialist to the location of that CF member. This study has shown that the

compared systems meet the CF requirements, are currently available, and can provide just what the doctor ordered.

Recommendations for Further Study

The conclusion that all three compared systems are viable satellite means of delivering telemedicine between a deployed CF force and a Canada-based hospital is based on systems that are viable under the current developed requirements with no criteria being more important than another. The recently formed Canadian telemedicine working group as part of the DND Special Committee on Medical Review will be determining the most important criteria, which criteria if any need to be weighted for any future comparisons, if any additional criteria need to be added, and the time phasing of any Phase I and Phase II satellite system delivered telemedicine systems. The first question of which criteria are the most important will need to be answered before the implementation of any telemedicine system in Phase I can begin. The remaining questions will need to be researched and answered in order to prepare for Phase II for any satellite-delivered CF telemedicine system.

1. What criteria from this study are the most important to the CF?
2. Will those same most important criteria for Phase I be the most important criteria for Phase II?
3. What new requirements will be added to a Phase II system?
4. What increase in satellite bandwidth will those requirements add?
5. Will there be a requirement to integrate the telemedicine information into any existing or future DND specific communications systems, whether in support of the Canadian Army, Navy or Air Force?

6. What satellite service providers can best meet any growth in requirements?
7. Are there any financial benefits to a long-term partnership with those service providers?
8. What satellite teleport or teleports should be used in Canada to receive the deployed force's information and is one required on each coast?
9. Who is the decision-making authority for use of limited space segment bandwidth when two simultaneous CF deployments require use of the telemedicine system bandwidth?
10. How will the developing NATO standards for telemedicine effect a Phase II selection for a CF telemedicine system?
11. What developments at the Fort Gordon Battle Lab will be applicable for a CF telemedicine system particularly for tactical terrestrial communications?
12. How can worldwide commercial space segment providers be integrated into existing Canadian domestic satellite services?
13. Will the 2006 to 2008 fielding of Advanced Extra High Frequency (AEHF) terminals and Canadian owned AEHF military satellite bandwidth be available for telemedicine use?
14. Will the Phase II telemedicine system have to be modified in order to use the AEHF system and how will it be linked into the Canada-based support hospital?

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